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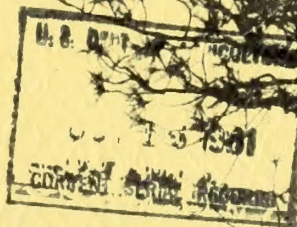
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CLASSES OF PONDEROSA PINE IN NEW MEXICO AND ARIZONA
SUSCEPTIBLE TO ATTACK BY THE SOUTHWESTERN PINE
BEETLE AND ASSOCIATED BARK BEETLES

by

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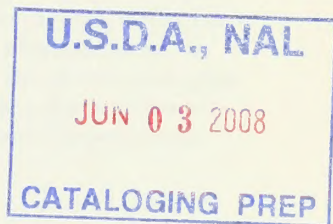
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^{1/} Central headquarters maintained in cooperation with Colorado State University at Fort Collins. The study was completed at the Station's Forest Insect Laboratory at Albuquerque, New Mexico.

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Bark beetle control in the United States is largely done by direct methods. These include: (1) Killing the overwintering brood by felling, peeling, and burning the bark of infested trees; (2) salvage logging the infested trees from the woods, the wood is utilized, and the insects are killed in the refuse burner or mill pond; and (3) spraying either the standing or felled infested tree with insecticides.

These methods are effective, but results may be temporary and not directed at the cause of the insect outbreak. An ideal way of keeping bark beetle populations under control would be by silvicultural methods based on a susceptibility classification system.

The aim of the system is to sort the trees in a stand according to their susceptibility to bark beetle attack. Trees classed as high-risk can be removed by a sanitation-salvage cutting that captures the loss and possibly prevents outbreaks. The success of the system is dependent on three things: (1) The species of bark beetles involved prefer trees of low vigor; (2) low-vigor trees can be recognized in the stand and their characteristics defined; and (3) the high-risk trees constitute a low percentage of the stand that can be removed without upsetting the ecology of the residual stand.

Keen^{2/} in 1936 and Salman and Bongberg^{3/} in 1942 developed systems that proved to be highly successful against the western pine beetle (Dendroctonus brevicomis Lec.) on the inland ponderosa pine stands of California and Oregon. Because of the similarity of the habits of the southwestern pine beetle (Dendroctonus barberi Hopk.) to those of the western pine beetle, and similarity of the pine stands, it was only natural that the methods be tested in the ponderosa pine stands of the Southwest. Such tests were started in 1952 when a Forest Insect Laboratory, a field unit of the Rocky Mountain Forest and Range Experiment Station, was established at Albuquerque, New Mexico.^{4/}

^{2/} Keen, F. P. Relative susceptibility of ponderosa pines to bark-beetle attack. Jour. Forestry 34: 919-927, illus. 1936.

^{3/} Salman, K. A., and Bongberg, J. W. Logging high-risk trees to control insects in the pine stands of northeastern California. Jour. Forestry 40: 533-539, 1942.

^{4/} Mortality plots were established by J. W. Bongberg and R. K. Bennett in 1953 and 1954.

Keen's classification as modified by Thomson^{5/} for the Southwest used 4 age groups each of which is divided into 4 vigor classes resulting in a total of 16 age and vigor divisions (tables 1 and 2). The age groups are determined on the basis of d.b.h., bark color and surface texture, shape of the top, and the branching habit. The vigor classification groups trees into classes according to their relative rates of growth, from the best represented by A to the poorest represented by D. Size of crown and the abundance and condition of the needles are the best indicators of vigor.

Table 1. --Description of Keen's age classes as modified by Thomson for the Southwest

Character	Class 1	Class 2	Class 3	Class 4
Maturity	Young	Immature	Intermediate - mature	Mature - overmature
Age	Usually less than 75 years	Usually less than 150 years	Approximately 150-225 years	Approximately 225 years and over
Diameter breast high	Under 12 inches	Seldom over 24 inches	Usually less than 36 inches	Usually large
Bark color	Dark gray to black	Black to dark reddish brown	Reddish brown shading to black in the top	Reddish brown to yellow
Bark plates	No plates, rough bark, deeply furrowed with narrow ridges between fissures	Ridges or very narrow plates between the fissures	Moderately large plates between the fissures	Plates usually very wide, long and smooth
Tops	Usually pointed	Pointed or slightly rounding; never flat	Usually pyramidal or rounded, occasionally pointed	Usually flat and making no further height
Branches	Upturned and whorls distinct	Mostly upturned and whorls distinct for upper half of crown, flattening out with less distinct whorls in lower half	Upturned in upper third of crown; those in the middle horizontal, and drooping in lower third of crown	Mostly large drooping, gnarled or crooked; whorls indistinct and incomplete

Salman and Bongberg defined four risk groups (table 3). Characters used in defining risk are concerned with the apparent health or vigor of the crown as evidenced by the foliage, twigs, and branches. Factors of age, crown form, and crown position do not enter into their appraisal of risk.

As stated by Miller and Keen,^{6/} the essential difference between the two systems is one of distinguishing inherent vigor (Keen's classes) from current health (risk ratings).

^{5/} Thomson, Walter G. A growth rate classification of southwestern ponderosa pine. Jour. Forestry 38: 547-553, illus. 1940.

^{6/} Miller, J. M., and Keen, F. P. Biology and control of the western pine beetle. U. S. Dept. Agr. Misc. Pub. 800, 381 pp., illus. 1960.

Table 2. --Description of Keen's crown vigor classes as modified by Thomson for the Southwest

Character	Class A	Class B	Class C	Class D
Crown vigor	Full, vigorous	Fair to moderately vigorous	Fair to poor vigor	Usually of very poor vigor
Crown length and width	55 percent or more of the total height of the tree; average width or wider	Less than 55 percent, but 35 percent or more of height of the tree, or a longer crown if narrow or somewhat thin; either short wide crowns or long narrow ones	Either short (from 20-25 percent of the height of the tree, if foliage is of average thrift) or long, sparse and narrow	Less than 20 percent of the total height of tree; often quite thin and sickly
Foliage	Usually very dense and thrifty, the individual leaves being of average length or longer	Usually thrifty, of full to medium density and of average length	Usually short and from medium to poor density; of normal length and density when confined to top third of tree	Usually short and of poor to very poor density, very sparse and scattered or only partially developed
Position	Usually isolated or dominant	Usually codominant but often isolated or dominant	Usually inter-mediate or sometimes codominant, but rarely isolated	Usually suppressed or intermediate or if dominant or codominant it is suffering from some vigor-reducing ailment such as severe insect attack, lightning strike, or very old age
Diameter	Large for age	Above average for age	Usually below average	Usually decidedly subnormal, but very old and damaged trees are often of large diameter

Table 3. --Descriptions of Salman and Bongberg's risk ratings

Risk rating	Symptoms
Risk I--Low risk	Full-foliaged, healthy-appearing crowns. Foliage of healthy appearance, needles usually long and coarse, color good dark green. Practically all twigs with normal foliage complement. No weakened parts of crown.
Risk II--Moderate risk	Fair to moderately healthy crowns, imperfect in spots. Foliage mostly healthy, needle length average or better, color fair to good. Some twigs or branches may lack foliage, but such injury should not be localized to form definite "weak" spots in crown.
Risk III--High risk	Crowns of fair to poor health, somewhat ragged or thin in parts of crown. Foliage in parts of crown thin, bunchy, or unhealthy; needles average to shorter than average in length; color fair to poor. Some to many twigs or branches lacking foliage, some to many twigs or branches fading or dead. Small localized weakened parts of crown usually present.
Risk IV--Very high risk	Crowns in poor condition, ragged or thin, often showing evidence of active insect infestations in upper parts. Foliage thin or bunchy, needles short or sparse, color poor. Twigs and branches dead or dying, parts of crown definitely weakened. Active top-killing or partial infestations often present.

METHODS OF TESTS IN SOUTHWEST

During the 1953 and 1954 field seasons, forty 10-acre plots were established in virgin ponderosa pine stands in Arizona and New Mexico. Table 4 gives the plot locations and information on the stands. Figure 1 shows a typical plot and how the trees were numbered.

Table 4. --Summary of plot locations and stand characteristics

Plot locations	10-acre plots	Volume per acre			Trees per acre		
		Lowest	Highest	Average	Lowest	Highest	Average
	Number	- - - -	Board feet	- - - -	- - - -	Number	- - - -
Navajo Indian Reservation	20	4, 197	16, 067	8, 914	9.9	40.2	21.4
National forests:							
Apache	7	5, 451	11, 966	8, 429	15.5	39.3	26.4
Kaibab	4	17, 293	19, 274	18, 225	37.0	46.0	39.5
Santa Fe	3	4, 828	22, 521	13, 496	24.8	33.6	30.0
Sitgreaves	4	6, 765	17, 955	12, 388	17.4	34.9	26.6
Coconino	2	9, 684	12, 243	10, 963	24.9	36.2	30.5

Plot boundaries were marked with aluminum paint and each ponderosa pine tree 11.6 inches d.b.h. and over was numbered. Each tree was rated by Keen's Tree Classification System and also by Salman and Bongberg's Risk-Rating System. In addition, the d.b.h. height and volume were obtained for each tree.

The plots were examined each year from 1956-59 by a crew of three men to determine the amount of mortality caused by the southwestern pine beetle and associated bark beetles.

RESULTS

During the 5-year period of the study, 223 trees died on the plots. Bark beetles alone killed 126 trees (tables 5 and 6); lightning, wind, and pathological agents accounted for the remainder.

In volume, total loss amounted to approximately 119, 000 board feet of ponderosa pine timber on 400 acres during the 5-year period, an average of nearly 60 board feet per acre per year. The bark beetle-caused loss amounted to approximately 66, 000 board feet (tables 5 and 6).

The basis for the susceptibility of a class is the percent of trees killed in the class. In making a selective cut to remove expected mortality from a stand, it would be best to select trees in classes that sustain a high percent of loss and contain a small percentage of the total living stand.



Figure 1. --A typical plot with trees numbered with aluminum paint. Navajo Indian Reservation, Arizona.

Table 5. --Insect-caused mortality over 5-year period grouped by tree classes

Tree class ¹	: Live and : dead trees :	: Portion of : stand by : risk class :	: Dead trees :	: Portion of : risk class : dead :	: Volume : loss :	: Portion vol- : ume loss : in class :	: Portion of : total vol- : ume loss :
	<u>Number</u>	<u>Percent</u>	<u>Number</u>	<u>Percent</u>	<u>M b.m.</u>	<u>Percent</u>	<u>Percent</u>
HIGH RISK:							
4D	90	0.9	14	15.6	8.2	14.8	12.4
3D	405	3.9	26	6.4	9.5	9.4	14.4
2D	152	1.5	4	2.6	1.0	6.4	1.5
1D	7	.1	1	14.3	0	0	0
4C	461	4.4	14	3.0	11.2	3.4	17.0
3C	1,658	15.9	31	1.9	14.8	2.2	22.4
LOW RISK:							
2C	1,187	11.4	10	0.8	1.3	.7	2.0
1C	78	.8	1	1.3	² 0	.6	.1
4B	731	7.0	9	1.2	9.6	1.4	14.5
3B	1,868	17.9	8	.4	5.8	.9	8.8
2B	1,475	14.2	3	.2	.6	.2	.9
1B	180	1.7	0	0	0	0	0
4A	347	3.3	2	.5	2.6	.7	3.9
3A	704	6.8	3	.4	1.4	.3	2.1
2A	923	8.9	0	0	0	0	0
1A	146	1.4	0	0	0	0	0
Total or average	10,412	100.0	126	1.2	66.0	1.7	100.0

¹ Categories of high and low risk as defined by Keen (see footnote 7).² 50 bd. ft. loss in this class.

Table 6. --Insect-caused mortality over 5-year period grouped by risk classes

Risk class	: Live and : dead trees :	: Portion of : stand by : risk class :	: Dead trees :	: Portion of : risk class : dead :	: Volume : loss :	: Portion vol- : ume loss : in class :	: Portion of : total vol- : ume loss :
	<u>Number</u>	<u>Percent</u>	<u>Number</u>	<u>Percent</u>	<u>M b.m.</u>	<u>Percent</u>	<u>Percent</u>
4	241	2.3	38	15.8	18.3	17.9	27.7
3	817	7.8	24	2.9	16.0	4.6	24.3
2	3,183	30.6	41	1.3	20.2	1.5	30.6
1	6,171	59.3	23	.4	11.5	.5	17.4
Total or average	10,412	100.0	126	1.2	66.0	1.7	100.0
<u>Cumulative</u> <u>risk class</u>							
4	241	2.3	38	15.8	18.3	17.9	27.7
4 + 3	1,058	10.1	62	5.9	34.3	7.6	52.0
4 + 3 + 2	4,241	40.7	103	2.4	54.5	3.1	82.6

TOTAL MORTALITY BY TREE CLASSES

Table 7 is a summary of the total mortality data by each tree class. Classes 1C and 4B were placed in the low-risk category even though they showed a fairly high percentage of class killed. Had the study been more extensive and continued several more years, these classes would probably have been in the low-risk group.

Table 7. --Mortality by all causes over 5-year period grouped by tree classes

Tree class ¹	: : Live and : dead trees	: : Portion of : stand by : risk class	: : Dead trees	: : Portion of : risk class : dead	: : Volume : loss	: : Portion vol- : ume loss : in class	: : Portion of : total vol- : ume loss
	Number	Percent	Number	Percent	M b.m.	Percent	Percent
HIGH RISK:							
4D	90	0.9	22	24.4	14.9	27.0	12.5
3D	405	3.9	41	10.1	12.4	12.4	10.4
2D	152	1.5	7	4.6	1.2	7.3	1.0
1D	7	.1	1	14.3	² 0	3.3	0
4C	461	4.4	30	6.5	24.7	7.6	20.8
3C	1,658	15.9	52	3.1	21.7	3.3	18.3
LOW RISK:							
2C	1,187	11.4	16	1.3	4.0	2.1	3.4
1C	78	.7	2	2.6	.1	1.1	.1
4B	731	7.0	20	2.7	20.4	3.1	17.2
3B	1,868	17.9	15	.8	10.3	1.6	8.7
2B	1,475	14.2	6	.4	.4	.2	.3
1B	180	1.7	1	.6	.6	4.8	.5
4A	347	3.3	6	1.7	6.9	1.8	5.8
3A	704	6.8	3	.4	1.0	.3	.8
2A	923	8.9	1	.1	.2	.2	.2
1A	146	1.4	0	0	0	0	0
Total or average	10,412	100.0	223	2.1	118.8	3.0	100.0

¹ Categories of high and low risk as defined by Keen (see footnote 7).

² 50 bd. ft. loss in this class.

Of the total stand involved in the study, 26.7 percent fell into the high-risk category. During a 5-year interval, approximately 74.9 M b.m. or 63.0 percent of the total volume loss occurred in this group.

TOTAL MORTALITY BY RISK CLASSES

Table 8 is a presentation of the total mortality data by the risk-rating system.

Risk class 4 contained only 2.3 percent of the green stand, but 25.6 percent of the volume loss, amounting to approximately 30.4 M b.m., which occurred during the 5-year period. Risk classes 4 and 3 combined contained 47.6 percent of the total volume loss or approximately 56.6 M b.m. in only 10.1 percent of the living stand.

Table 8. --Mortality by all causes over 5-year period grouped by risk classes

Risk class	: : Live and : dead trees :	: : Portion of : stand by : risk class :	: : Dead trees :	: : Portion of : risk class : dead :	: : Volume : loss :	: : Portion vol- : ume loss : in class :	: : Portion of : total vol- : ume loss :
	<u>Number</u>	<u>Percent</u>	<u>Number</u>	<u>Percent</u>	<u>M b.m.</u>	<u>Percent</u>	<u>Percent</u>
4	241	2.3	57	23.7	30.4	29.8	25.6
3	817	7.8	47	5.8	26.2	7.6	22.0
2	3,183	30.6	67	2.1	36.9	2.8	31.1
1	6,171	59.3	52	.8	25.3	1.2	21.3
Total or average	10,412	100.0	223	2.1	118.8	3.0	100.0
<u>Cumulative</u> <u>risk class</u>							
4	241	2.3	57	23.7	30.4	29.8	25.6
4 + 3	1,058	10.1	104	9.8	56.6	12.7	47.6
4 + 3 + 2	4,241	40.7	171	4.0	93.5	5.3	78.7

INSECT-CAUSED MORTALITY BY TREE CLASSES

Arranging the insect-caused mortality by tree classes (see table 5), 44.7 M b.m. of the volume loss fell in the high-risk category. These classes would isolate 67.7 percent of the volume loss caused by bark beetles from 26.7 percent of the stand in the 5-year period.

INSECT-CAUSED MORTALITY BY RISK CLASSES

Risk class 4, with 2.3 percent of the living stand, sustained a loss of 17.9 percent of its volume and 27.7 percent of the total volume loss due to bark beetles (see table 6). Risk classes 4 and 3 combined accounted for 52.0 percent of the volume loss (34.3 M b.m.) in 10.1 percent of the living stand.

DISCUSSION

Keen^{7/} tested the two methods of tree selection in a study in Oregon. The results of the present study were similar to those reported by Keen. In the following tabulation the two studies are compared on the basis of bark beetle-caused mortality only. The comparison shows the percentage of trees killed and percentage of the living stand in the high-risk category:

^{7/} Keen, F. P. Ponderosa pine tree characteristics indicative of high risk to pine beetle attack. U. S. Forest Serv., Calif. Forest and Range Expt. Sta., Prog. Rpt. (1938-52). 50 pp. 1954. [Unpublished report.]

<u>Rating method</u>	<u>Portion of tree loss in high risk classes</u> (Percent)	<u>Portion of green stand in high risk classes</u> (Percent)
Keen's tree classes: ^{8/}		
Oregon	66.8	34.8
Arizona and New Mexico ^{9/}	67.7	26.7
Salman and Bongberg's risk classes 3 and 4:		
Oregon	65.5	19.6
Arizona and New Mexico	52.0	10.1

It appears the identification of susceptible trees was better in the Arizona and New Mexico study than in the Oregon study. It must be kept in mind, however, that the Oregon study lasted 10 years. If the Arizona and New Mexico studies were continued, a larger percentage of the mortality would come from the lower risk classes.

It appears from the data obtained in the foregoing study that both methods--a marking system based on Keen's Tree Classification as modified by Thomson, and Salman and Bongberg's Risk-Rating System--can be adapted to marking ponderosa pine stands in the Southwest.

^{8/} All D crowns and classes 4C and 3C.

^{9/} This study used Keen's tree classes as modified by Thomson (see footnote 5).



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